Species Report of *Kadua fluviatilis (kamapuaʻa)*
Version 1.0

Kadua fluviatilis in bloom at Mt. Hāʻupu, Kauaʻi, photo by Natalia Tangalin

December 2020
Pacific Islands Fish and Wildlife Office
U.S. Fish and Wildlife Service
Honolulu, HI

This document was prepared by Michelle Clark, Lauren Weisenberger and Fred Amidon. We received valuable input and assistance from the following experts: Kenneth R. Wood and Merlin Edmonds of the National Tropical Botanical Garden and Susan Ching Harbin of the Hawai‘i Department of Land and Natural Resources, Divison of Forestry and Wildlife. We greatly appreciate their guidance and support, which resulted in a more robust report.

Suggested reference:
U.S. Fish and Wildlife Service. 2020. Species Report for *Kadua fluviatilis* (kamapua‘a). Pacific Islands Fish and Wildlife Office, Pacific Islands Interior Region 12, Portland OR. 30 pages.

EXECUTIVE SUMMARY

This report summarizes the results of a Species Report completed for *Kadua fluviatilis* (kamapuaʻa) to assess the overall viability of the species. To assess the viability of the species, the U.S. Fish and Wildlife Service (Service), used the three conservation biology principles of resiliency, redundancy, and representation (together the 3Rs). Specifically, we identified the species' needs and ecological requirements for survival and reproduction at the individual, population, and species levels, and identified the factors influencing viability for *K. fluviatilis*. We evaluated the species' current condition based on resiliency, redundancy, and representation.

Kadua fluviatilis (kamapuaʻa) is a climbing shrub in the coffee family (Rubiaceae). It is an endemic species found only on the islands of Kauaʻi and Oʻahu in the Hawaiian islands. *K. fluviatilis* was first described by Charles N. Forbes in 1910 from the type locality on the borders of the upper Wahiawa stream on Oʻahu. There are an estimated 78 to 128 individuals on Kauaʻi and less than 150 indivudals on Oʻahu. *Kadua fluviatilis* is found in several habitat types including, lowland mesic and wet forests, lowland mesic and wet shrublands, and wet cliffs. These habitats provide the resource needs for individual plants and populations of *K. fluviatilis*. Suitable habitat for *K. fluviatilis* occurs in the wet forests of the northern valleys of Kauaʻi island at Upper Mānoa, Limahuli and Hanakāpʻiʻai. Populations also occur along the windward slopes of central Kauaʻi at ʻIole ridge below the summit of the island at Kawaikini. Several hundered individuals were observed close to the summit of Mt. Hāʻupu in southeastern Kauaʻi in 2005. On the island of Oʻahu, populations occur in the Koʻolau mountain range from Pūpūkea to Mānoa. Suitable habitat remains at Helemano, Kaukonahua, Kawaiʻiki Gulch, Punaluʻu, Kaluanui Gulch, Koloa Gulch, Maʻakua and Kaipapaʻu, however, extant populations have only recently been observed at Punaluʻu, Kaluanui Gulch and Kaipapaʻu. Overall, the species is declining as a result of competition from invasive nonnative plants, animals, climate change and stochastic events such as landslides.

In this Report, we evaluate resiliency for *Kadua fluviatilis* based on the metrics of population size and habitat quality. In total, 16 populations were historially known for the species. Populations are considered resilient if they contain large numbers of individuals and a population structure that includes all life stages (seedlings, immature individuals and mature individuals) to support positive or stable population growth. We have limited information on population structure, however, mature and immature individuals have been reported within historic population units. Currently there are two population units on Oʻahu and five population units on Kauaʻi. Only two populations (both on Kauaʻi) are in areas in which some threats are being addressed (invasive plants at Mt. Hāʻupu and invasive plants and feral ungulates at Limahuli). Therefore, the resiliency for *K. fluviatilis* on the species level is low in the current condition due to the low of number of individuals (228 to 278 within the seven population units), as well as the decrease in the extent and quality of habitat, and the degree of threats remaining in current populations.

We evaluate redundancy for *Kadua fluviatilis* based on the metric of the number of populations and their distribution across the known range of the species. Historically, the species was known from nine populations on Oʻahu and seven populations on Kauaʻi. Since no concentrated efforts focusing on surveying for *K. fluviatilis* have been conducted we cannot be certain of the current distribution, however, it is likely populations have been lost due to habitat loss and degradation

which decreases redundancy. Currently only two populations are known on O‘ahu and five populations on Kaua‘i. The loss of populations reduces the species range and increases the risk of extirpation. Therefore, the redundancy of *K. fluviatilis* is low due to the loss of populations and species range constriction.

We define representation for *Kadua fluviatilis* based on the number of populations occupying the different habitat types used by *K. fluviatilis*. The distribution of historic and current populations occurs in five habitat types on two islands. Three population units occur in lowland wet forest and two population units occur in lowland wet shrubland whereas a single population represents the remaining habitat types. However, the total number of individuls in each popuation unit represented by more than one habitat type is low (11 to 32 individuals in lowland wet forest and 26 individuals in lowland wet shrubland), thus these populations have low resiliency. Therefore, representation for *K. fluviatilis* is low.

The current condition of *Kadua fluviatilis* is described as having seven populations on two islands. Overall, it is likely that individuals in populations have generally been decreasing due to existing threats throughout most of the species’ range. Some redundancy and representation is maintained in *ex situ* seed storage and greenhouses, and reintroduced individuals, however, recruitment as a result of these reintroductions has yet to be documented. As this species has low resiliency, low representation, and low redundancy in the current condition, the overall viability of this species is low.

Table of Contents

List of Tables

List of Figures

INTRODUCTION

Kadua fluviatilis (kamapuaʻa) is a climbing shrub in the coffee family (Rubiaceae) (Wagner et al. 1999, pp. 1142-1144). It is an endemic species to the islands of Kauaʻi and Oʻahu in the Hawaiian Islands. *K. fluviatilis* was first described by Charles N. Forbes in 1910 from the type locality on the borders of the upper Wahiawa stream on Oʻahu (Forbes 1913, p. 6). This species occupies both lowland mesic and lowland wet ecoystems. There are an estimated 128 individuals on Kauaʻi and fewer than 150 individuals on Oʻahu (NTBG 2020, HBMP 2010, S. Ching Harbin, Hawaiʻi Deparment of Land and Natural Resources 2020, pers. comm.).

Species Report Overview

This Species Report summarizes the biology and current status of *Kadua fluviatilis* and was conducted by Pacific Islands Fish and Wildlife Office. It is a biological report that provides an in-depth review of the species' biology, factors influencing viability (threats and conservation actions), and an evaluation of its current status and viability.

The intent is for the Species Report to be easily updated as new information becomes available, and to support the functions of the Service's Endangered Species Program. As such, it will serve as a living document and biological foundation of other documents such as recovery plans, status in biological opinions, and 5-year reviews.

Regulatory History

Kadua fluviatilis was listed as an endangered species on September 30, 2016 (81 FR 67786, U.S. Fish and Wildlife Service [USFWS] 2016). No critical habitat has been designated for this species. A recovery plan is currently in preparation.

Methodology

We used the best scientific data available to us, including peer-reviewed literature, grey literature (government and academic reports), and expert elicitation.

To assess the current status and viability of *Kadua fluviatilis*, we identified population units. The classic definition of a population is a self-reproducing group of conspecific individuals that occupies a defined area over a span of evolutionary time, an assemblage of genes (the gene pool) of its own, and has its own ecological niche. However, due to information gaps, we could not assess the viability of *K. fluviatilis* using this definition. The Hawaii and Pacific Plants Recovery Coordinating Committee revised its recovery objectives guidelines in 2011 and included a working definition of a population for plants: "a group of conspecific individuals that are in close spatial proximity to each other (*i.e.*, less than 1,000 meters apart), and are presumed to be genetically similar and capable of sexual (recombinant) reproduction" (HPPRCC 2011, p. 1). Based on this working definition, maps were created to display population units. In an effort to protect the sensitivity of species data, we created maps with symbol markers rather than displaying species points or polygons. We created the symbols in steps. First, we added a 500-meter buffer around each individual species point and polygon. We then dissolved all buffer areas intersecting each other into a single shape. Next, we created a centroid (i.e., point representing the center of a polygon) within each dissolved buffer area. The symbol marker represents the centroid. Finally, the Disperse Marker tool in ArcGIS Pro was used shift symbol markers that were overlapping so they would all be visible at the scale of the map. All points and polygons were used in this process, regardless of observation date or current status (historical, current, extant, or extirpated), to represent the known range of the species.

Species Viability

The Species Report assesses the ability of *Kadua fluviatilis* to maintain viability over time. Viability is the ability or likelihood of the species to maintain populations over time, i.e., likelihood of avoiding extinction. To assess the viability of *K. fluviatilis* we used the three conservation biology principles of resiliency, redundancy, and representation, or the "3Rs" (Figure 1; USFWS 2016, entire). We will evaluate the viability of a species by describing what the species needs to be resilient, redundant, and represented, and compare that to the status of the species based on the most recent information available to us.

Definitions

Resiliency is the capacity of a population or a species to withstand the more extreme limits of normal year-to-year variation in environmental conditions such as temperature and rainfall extremes, and unpredictable but seasonally frequent perturbations such as fire, flooding, and storms (i.e., environmental stochasticity). Quantitative information on the resiliency of a population or species is often unavailable. However, in the most general sense, a population or species that can be found within a known area over an extended period of time (e.g., seasons or years) is likely to be resilient to current environmental stochasticity. If quantitative information is available, a resilient population or species will show enough reproduction and recruitment to maintain or increase the numbers of individuals in the population or species, and possibly expand the range of occupancy. Thus, resiliency is positively related to population size and growth rate, and may also influence the connectivity among populations.

Redundancy is having more than one resilient population distributed across the landscape, thereby minimizing the risk of extinction of the species. To be effective at achieving redundancy, the distribution of redundant populations across the geographic range should exceed the area of impact of a catastrophic event that would otherwise overwhelm the resilient capacity of the populations of a species. In the report, catastrophic events are distinguished from environmental stochasticity in that they are relatively unpredictable and infrequent events that exceed the more extreme limits of normal year-to-year variation in environmental conditions (i.e., environmental stochasticity), and thus expose populations or species to an elevated extinction risk within the area of impact of the catastrophic event. Redundancy is conferred upon a species when the geographic range of the species exceeds the area of impact of any anticipated catastrophic event. In general, a wider range of habitat types, a greater geographic distribution, and connectivity across the geographic range will increase the redundancy of a species and its ability to survive a catastrophic event.

Representation is having more than one population of a species occupying the full range of habitat types used by the species. Alternatively, representation can be viewed as maintaining the breadth of genetic diversity within and among populations, in order to allow the species to adapt to changing environmental conditions over time. The diversity of habitat types, or the breadth of the genetic diversity of a species, is strongly influenced by the current and historic biogeographical range of the species. Conserving this range should take into account historic latitudinal and longitudinal ranges, elevation gradients, climatic gradients, soil types, habitat types, seasonal condition, etc. Connectivity among populations and habitats is also an important consideration in evaluating representation.

The viability of a species is derived from the combined effects of the 3Rs. A species is considered viable when there are a sufficient number of self-sustaining populations (resiliency) distributed over a large enough area across the range of the species (redundancy) and occupying a range of habitats to maintain environmental and genetic diversity (representation) to allow the species to persist indefinitely when faced with annual environmental stochasticity and infrequent catastrophic events. Common ecological features are part of each of the 3Rs. This is especially true of connectivity among habitats across the range of the species. Connectivity sustains dispersal of individuals, which in turn greatly affects genetic diversity within and among populations. Connectivity also sustains access to the full range of habitats normally used by the species, and is essential for re-establishing occupancy of habitats following severe environmental stochasticity or catastrophic events (see Figure 1 for more examples of overlap among the 3Rs). Another way the three principles are inter-related is through the foundation of population resiliency. Resiliency is assessed at the population level, while redundancy and representation are assessed at the species level. Resilient populations are the necessary foundation needed to attain sustained or increasing representation and redundancy within the species. For example, a species cannot have high redundancy if the populations have low resiliency. The assessment of viability is not binary, in which a species is either viable or not, but rather on a continual scale of degrees of viability, from low to high. The health, number and distribution of populations were analyzed to determine the 3Rs and viability. In broad terms, the more resilient, represented, and redundant a species is, the more viable the species is. The current understanding of factors, including threats and conservation actions, will influence how the 3Rs and viability are interpreted for *Kadua fluviatilis.*

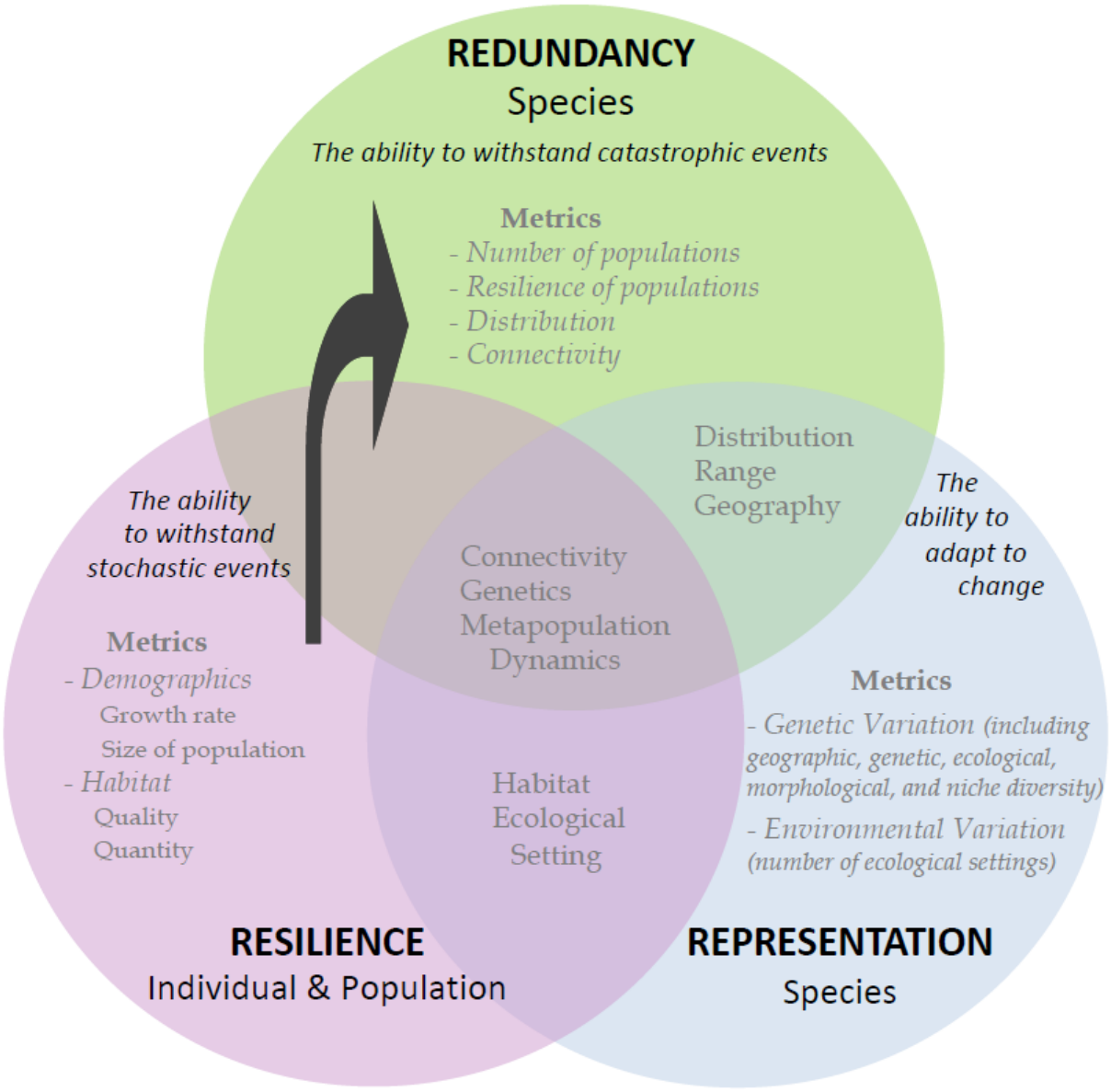

Figure 1. The three conservation biology principles of resiliency, redundancy, and representation, or the "3Rs".

SPECIES ECOLOGY

Species Description

Kadua fluviatilis was first described by C.N. Forbes in 1910 (Forbes 1913, p. 6). Forbes found the type locatily specimen on the borders of the upper Wahiawa stream within the Koʻolau mountain range on Oʻahu. It grows in mesic to wet forests at elevations ranging from 160 to almost 4,000 feet (ft), (48 to 1,219 meters (m)). It occurs on Kauaʻi and on Oʻahu in the Koʻolau Mountains from Pūpūkea to Mānoa. (Wagner et al. 1999, p. 1,144).

Kadua fluviatilis belongs to the family Rubiaceae (coffee family). The coffee family is among the largest families of flowering plants and comprises roughly 500 genera and more than 6,500 species, primarily in the tropical and subtropical regions. It is represented in Hawai‘i by 52 endemic species in six genera (Wagner et al. 1999, p. 1,111).

Until recently, most modern taxonomic and floristic treatments of native Hawaiian *Kadua* species were in the genus *Hedyotis*. However, a recent study of these species focusing on seed morphology, as well as fruit, inflorescence, and corolla characters, demonstrated that seeds of Hawaiian and certain South Pacific species are different from other Asian, Pacific and North American species of *Hedyotis*. Based these differences, species belonging to the former group have been transferred to the genus *Kadua* Cham. & Schltdl. (Terrell et al. 2005, p. 819). There are about 30 species of *Kadua*, all of which are endemic to Pacific islands and the majority (22) of species are in the Hawaiian islands.

Kadua fluviatilis are climbing shrubs, which have an unpleasant odor when the stems are bruised. *Kadua fluviatilis* is very similar to *Kadua acuminata* but differs by having larger flowers with thicker, waxy, white corollas. Wagner et al. (1999) suggest that *K. fluviatilis* might best be treated as a subspecies of *K. acuminata*. Furthermore, they state plants from Sacred Falls, O‘ahu described by Degener and Fosberg in 1943 as *Hedyotis* (*Kadua*) *fluviatilis* f. *breviflora* may represent hybrids with *K. acuminata* as both species grow in the area (Wagner et al. 1999, p. 1,144).

Kadua fluviatilis has 3-sided stems which can vary from 1 to 8 ft (0.3 to 2.4 m) long with short lateral (side) branches. The leaves are usually widely spaced and firm-chartaceous, in other words, they have a papery texture. They are longer than they are wide and range in size from 3 to 6.5 inches (in) (7.6 to 16.5 centimeters (cm)) long with a width of 1 to 2 in (2.54 to 5.08 cm). The flowers are fairly large, 0.75 to 1 in (1.9 to 2.54 cm) long and almost 0.75 in (1.9 cm) in diameter, and are perfect (hermaphroditic) and pistillate (female). *Kadua fluviatilis* flowers are white, fleshy and waxy and grow in clusters where the leaves join the stems (see Figure 2).

Figure 2. *Kadua fluviatilis* flowers in lowland wet forest, Upper Mānoa Valley, Kauaʻi. Photo by M. Clark, USFWS.

The fruit of *K. fluviatilis* is a woody capsule about 3/8 to 1/2 in (0.95 to 1.27 cm) in diameter. It is more or less round, and strongly quadrangular or winged. When the seed capsule is mature, it dehisces (opens up) along its seams. The seeds are translucent reddish brown and wedge shaped (Wagner 1999, p. 1,144).

Reproduction of *Kadua fluviatilis* includes seeds that likely drop near the parent plant. It is possible that the small "winged" capsules may be carried by wind or water via floatation. Seed-eating birds may be a potential dispersal vector, and seeds could be potentially carried in mud on the feet of birds (Sakai et al. 1995, p. 2527; Carlquist 1966, p. 314, 327).

Kadua fluviatilis individuals flower sporadically and nealy year round (Eliot and Tamashiro 2009, NTBG 2020). This species was observed with seed capsules during the months of March, May, August, September, October, November and December. There were no observations in the month of April (NTBG 2020), see Table 1 below.

Table 1. Flowering and seeding period for *Kadua fluviatilis* (National Tropical Botanical Garden 2020; USFWS unpublished data).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Flower	x	x	x		x	x	x	x	x	x	x	x
Seeds			x		x			x	x	x	x	x

The National Tropical Botanical Garden has successfully propagated *Kadua fluviatilis* by seeds and cuttings since 2001 (NTBG 2002). Fresh, untreated seeds of the closely-related *Kadua acuminata,* have an average germination rate of 72 percent (Lilleeng-Rosenberger 1996).

Individual Needs

The chromosome numbers for *Kadua fluviatilis* are 2n = 72 and 2n = c. 100 (Wagner et al. 1999).

Several phylogenetic studies have investigated the relationships of species with the family Rubiaceae. *Kadua fluviatilis* may be most closely related to *Kadua acuminata* based on studies on seed morphology (Terrell et al. 2005, p.822) and chloroplast and nuclear DNA markers (Kårehed et al. 2008, p. 851). However, Groeninckx et al. (2009, p.121) analyzed chloroplast data and found that the relationships within the genus *Kadua* remain mostly unresolved. Furthermore, they suggest broader sampling including more *Kadua* species and additional molecular markers are needed to discuss molecular evolution in the light of the seed morphological observations of Terrell et al. (2005). Wikstrom et al. (2013) conducted a Bayesian phylogenetic analyses of *Kadua* using plastid (*rps16*, *petD*) and nuclear (ITS, ETS) sequence data to test former taxonomic hypothesis. Their results suggest *K. fluviatilis* and *Kadua parvula,* a rare, small shrub only found on cliffs in the other mountain range on O‘ahu, the Wai‘anae Mountains, are the most closely related.

The life cycle of *Kadua fluviatilis* individuals is based on what is known about the species and is like most plants; seeds become seedlings, then become vegetative plants, and flowering plants. The life stages (seed, seedlings, vegetative, and flowering plants) of *K. fluviatilis* require very similar resources. At the seed stage, the seeds fall from the capsule that is located on the mother plant, and the seeds are deposited onto soil or another growing substrate. Competition with other species (including native plants) and/or nonnative invasive species can limit seedlings, vegetative plants, and flowering plants from getting the amount of water, soil, and sunlight that they need. *Kadua fluviatilis* is found in several habitat types including, lowland mesic and wet forests, lowland mesic and wet shrublands, and wet cliffs. These five habitats provide the resource needs for individual plants and populations of *K. fluviatilis*. Table 2 below summarizes the physical characteristics (rainfall, elevation and associated native plant species) of each habitat type prior to the arrival of humans and introduced species which have altered these plant communities. If all of the resource needs are met for this individual, than the species is highly resilient.

Lowland mesic shrubland receives the least amount of rainfall, followed by lowland mesic forest, lowland wet forest, lowland cliff and lowland wet shrubland. However, rainfall is only an indicator of available moisture, other factors such as topography, seasonality, soil moisture and canopy cover can generate wetter or drier conditions in a given habitat type (Gagne and Cuddihy 1999, p. 45). Lowland mesic and wet forests and lowland wet shrublands occur on substrates which vary from very weathered soils on older islands to rocky substrates on recent lava flows on younger islands. Lowland wet cliff substrates are generally thin over soft, highly weathered rock and thin mucky clays while lowland mesic shrubland substrates are shallow and may contain many rock outcrops. *Metrosideros polymorha* (‘ōhi‘a) occurs in each habitat type and many of the same plant genera overlap between habitat types. However, lowland mesic habitat types contain a higher diversity of tree species.

Table 2. Characteristics of habitat types occupied by *Kadua fluviatilis* (Ball et al. 2019 Clark et al. 2019, Lowe et al. 2019,Nelson et al. 2019, Wagner et al. 1999, Wood 2005 and 2012).

Habitat Type	Rainfall	Elevation	Substrate Type	Associated Native Species
Lowland mesic forest	47 to 149 in (120 to 380 cm)	98 to 5,249 ft (30 to 1600 m)	Very weathered soils on older islands to rocky substrates on recent lava flows on younger islands	*Metrosideros polymorpha*, *Acacia koa*, *Diospyros sandwicensis*, *Nestegis sandwicensis*, *Chrysodracon* spp., *Pritchardia kalae*, *Antidesma pulvinatum*, *Cryptocarya mannii*, *Alectryon micrococcus*, *Charpentiera* spp., *Flueggea neowawraea*, *Rhus sandwicensis*, *Pisonia* spp., *Canthium odoratum*, *Ctenitis squamigera*, *Doodia* spp., *Strongylodon ruber*, *Freycinetia arborea*
Lowland wet forest	59 to 197 in (150 to 500 cm)	328 to 3,937 ft (100 to 1200 m)	Very weathered soils on older islands to rocky substrates on recent lava flows on younger islands	*Acacia koa*, *Adenophorus* spp., *Alyxia stellata*, *Antidesma platyphyllum*, *Bobea elatior*, *Broussaisia arguta*, *Cibotium* spp., *Coprosma* spp. *Cyrtandra* spp., *Dicranopteris linearis*, *Diospyros sandwicensis*, *Diplopterygium pinnatum*, *Elaphoglossum* spp., *Freycinetia arborea*, *Kadua* spp., *Ilex ano*mala, *Machaerina* spp., *Melicope* spp., *Metrosideros polymorpha*, *Myrsine* spp., *Peperomia* spp., *Perrottetia sandwicensis*, *Pipturus* spp., *Pittosporum* spp., *Polyscias* spp., *Pritchardia* spp., *Psychotria* spp., *Smilax melastomifolia*, *Sticherus owhyensis*, *Syzgium sandwicensis*, *Touchardia latifolia*
Lowland wet shrubland	149 to 236 in (380 to 600 cm)	656 to 2,953 ft (200 to 900 m)	very weathered soils on older islands to rocky substrates on recent lava flows on younger islands	*Metrosideros polymorpha*, *Dicranopteris linearis*, *Broussaisia arguta*, *Melicope feddei*, *Psychotria mariniana*, *P. wawrae*, *Kadua affinis*, *Antidesma platyphylla*, *Alyxia stellata*, *Syzygium sandwicensis*, *Dubautia laxa*
Lowland wet cliff	98 to 197 in (250 to 500 cm)	656 to 2,953 ft	Soils are generally thin over soft, highly	*Dubautia* spp., *Lobelia* spp., *Vaccinium calycinum*, *Dicranopteris linearis* ,

		(200 to 900 m)	weathered rock and thin mucky clays	*Metrosideros polymorpha, Cibotium* spp., *Melicope* spp., *Myrsine* spp., *Freycinetia arborea, Kadua terminalis, Lycopodiella cernua, Machaerina angustifolia*
Lowland mesic shrubland	39 to 79 in (100 to 200 cm)	98 to 2,789 ft (30 to 850 m)	Soils are generally shallow and often dry out regularly and may contain many rock outcrops	*Metrosideros polymorpha, Xylosma hawaiiense, Ilex anomala, Kadua terminalis, Antidesma platyphyllum* var. *hillebrandii, Lobeila* spp., *Psychotria mariniana, Perrottetia sandwicensis Polyscias* spp., *Pittosporum gayanum, Pipturus* spp.

Population Needs

Based on historic and current observations we assume that stable population structure of *Kadua fluviatilis* should consist of plants in all life stages, including seedlings, immature, and mature, reproductive plants. A healthy population consists of abundant individuals within habitat patches of adequate area and quality to maintain survival and reproduction in spite of disturbance. Habitats supply the basic needs (food, air, water, space to grow, and shelter) of populations. Populations of *Kadua fluviatilis* occur in variety of habitats on Kauaʻi and Oʻahu. These habitats provide a diversity of environmental conditions for populations. The range of habitats may act as a buffer against changes in climatic variables such as precipitation and temperature. When populations occur in different habitat types, it is unlikely that all populations will experience the same changes in environmental conditions, thus ensuring that not all populations will fail due to unfavorable conditions.

Habitats can be negatively impacted by threats, such as invasive species. Populations of *Kadua fluviatilis* need habitats in which the degree of threats are at a low enough level that the habitat is able to continue to be suitable and supply the basic needs of the *K. fluviatilis* populations.

Suitable habitat for *Kadua fluviatilis* occurs in the wet forests of the northern valleys of Kauaʻi island at Upper Mānoa, Limahuli and Hanakāpiʻai (USFWS 2020, unpubl. data). Populations also occur along the windward slopes of central Kauaʻi at ʻIole ridge (Wood 2014, p. 2) below the summit of the island at Kawaikini. Several hundered individuals were observed close to the summit of Mt. Hāʻupu in southeastern Kauaʻi (Wood 2005, p.1). Upper Manoa and ʻIole are categorized as lowland wet forests whereas the location where *K. fluviatilis* occurs in Limahuli Valley is recognized as lowland wet cliff forest habitat. The summit of Mt. Hāʻupu is considered lowland mesic shrubland (USFWS 2020, unpul. data).

On the island of Oʻahu, populations occur in the Koʻolau mountain range from Pūpūkea to Mānoa (Wagner et al. 1999, p.1,144). Suitable habitat remains at Helemano, Kaukonahua Kawaiʻiki Gulch, Punaluʻu, Kaluanui Gulch, Koloa Gulch, Maʻakua and Kaipapaʻu (USFWS 2020, unpubl. data), however, extant populations have only recently been observed at Punaluʻu, Kaluanui Gulch and Kaipapaʻu (Ching Harbin 2020, pers.comm.). All of the Oʻahu habitat types are categorized as lowland wet forest, except for Maʻakua and Kaluanui Gulch, these areas are considered lowland wet shrublands (USFWS 2020, unpubl. data).

Populations occur in adjacent valleys both in the northern Koʻolau Mountains on Oʻahu and within the northern valleys of Kauaʻi. The dispersal ability and capacity for genetic exchange among populations of *Kadua fluviatilis* is unknown. The specific epithet, *fluviatilis,* literally means "growing in rivers and streams, of running water" (Elliot et al., 2009). Several populations on Kauaʻi and Oʻahu occur along streams. Perhaps seeds from individuals fall into streams and make their way to new riparian areas via streams and rivers, in addition to dispersal by gravity and birds. It is unknown if moths (as the suspected pollinator) are able to fly between populations to facilitate genetic exchange.

The genus *Kadua* in the Hawaiian Islands evolved from a hermaphroditic colonizer which resulted in over 20 endemic species (Sakai et al. 1995, p. 2519). The majority (66%) of these species are dimorphic (two distinct forms) in some form with the majority being gynodioecious; meaning that all of the flowers on an individual plant are female, or all the flowers on an individual are hermaphroditic (flowers have both male and female reproductive parts). This is the case for *Kadua fluviatilis* (Sakai et al. 1995, p. 2519). Therefore, female plants require a mechanism for outcrossing, to receive pollen from hermaphroditic plants in a population. This pollination mechanism is needed for reproduction to support future generations and encourage population stability. Moths are a likely pollinator of *K. fluviatilis* based on the pale white and tubular shaped flowers (Hawaiʻi Ecoregional Pollinator Guide 2013, p. 11). Pollinators are likely essential to maintaining outcrossing levels and genetic diversity.

Resiliency is the capacity of a population (or a species) to withstand stochastic disturbance events, however the survival rate of *Kadua fluviatilis* seedlings and growth rate needed to sustain populations in the presence of threats is unknown. Thus, we measure resiliency by the number of individuals in a population, population structure, and habitat quality.

Species Needs

Species need resilient populations that are redundant and represented.

Redundancy is the ability of *Kadua fluviatilis* to withstand catastrophic events and is measured by the number of populations (redundancy/duplication), distribution of the populations across the landscape, and connectivity among populations. In order to achieve redundancy, the distribution of *K. fluviatilis* populations across the geographic range should exceed the area of impact of a catastrophic event that would otherwise overwhelm the resilient capacity of the populations. Essentially, the more populations of *K. fluviatilis* and the broader the distribution of those populations, the more redundancy the species will exhibit, thereby increasing its ability to survive a catastrophic event. *Kadua fluviatilis* has been in cultivation since 2001 (NTBG 2002) as part of the National Tropical Botanical Gardens Living Collections and current efforts are underway to reintroduce this species in its former range (NTBG 2019, p. 4)). For *K. fluviatilis*, redundancy requires the presence of multiple, stable to increasing populations distributed across its different habitat types on Kauaʻi and Oʻahu.

Representation is the ability of *Kadua fluviatilis* to adapt to changing environmental conditions over time and can be measured by having one or more populations of a species occupying the full range of suitable habitat used by the species. Alternatively, representation can be viewed as maintaining the breadth of genetic diversity within and among populations, in order to allow the species to adapt to changing environmental conditions over time. Unique traits likely exist in populations in different habitat types and by island. We measure representation by the number of

extant and resilient populations within each habitat type and island. Given the diversity of habitats that *K. fluviatilis* occupies, it was likely more wide spread. We have no historical genetic information, however, we can assume that as populations decline and disappear, genetic diversity decreases. We have limited information on the connectivity of populations which would support genetic exchange and representation. However, connectivity decreases with habitat loss and fragmentation, thus we can assume that genetic diversity has likely decreased in the species over time. Representation is maintained in the *K. fluviatilis* species by having abundant individuals in stable to increasing populations that represent the existing full genetic diversity dispersed throughout its full range of habitat types on Kauaʻi and Oʻahu.

FACTORS INFLUENCING VIABILITY

Threats

Specific population-level threats to *Kadua fluviatilis* include habitat modification, destruction and predation by feral pigs (*Sus scrofa*) and goats (*Capra hircus*), stocahstic events such as landslides, and competition from nonnative plants, low population sizes, and inadequate regulatory mechanisms. Climate change may pose a threat to *K. fluviatilis* and is likely to intensify existing threats (USFWS 2016, p. 67779).

Feral ungulates (hooved animals), particularly feral pigs and goats, degrade habitat which reduces suitability of habitat for individuals of *Kadua* sp. to persist and constricts the area for populations to occupy (Lorence et al. 2010, p. 140). The mild climate of the islands, combined with the lack of competitors or predators, led to the successful establishment of large populations of these invasive mammals, to the detriment of native Hawaiian species and ecosystems. Native habitats where *Kadua fluviatilis* occurs are exposed to both direct and indirect negative impacts of invasive ungulates (Clark et al., 2019 p. 9). The effects of ungulates include the destruction of vegetative cover; trampling of plants and seedlings; direct consumption of native vegetation, including *K. fluviatilis*; soil disturbance; dispersal of invasive plant seeds on hooves and coats, and through the spread of seeds in feces; and creation of open disturbed areas conducive to further invasion by invasive plant species. All of these impacts can lead to the subsequent conversion of a native plant community to one dominated by invasive species (USFWS 2016, p. 67,827). Feral ungulates threaten *K. fluviatilis* throughout the species range. Only populations within ungulate-proof enclosures are considered to be protected.

In addition to these direct effects, because ungulates inhabit terrain that is often steep and remote, foraging and trampling contributes to severe erosion of watersheds and degradation of streams. Ungulates accelerate erosion which can cause landslides and dislodging stones from ledges which result in rock falls and landslides that damage or destroy native vegetation below (Cuddihy and Stone 1990, pp. 63–64).

Nonnative plants are a threat to *Kadua fluviatilis* as they compete for the same resources (water, space, nutrients, and light) that *K. fluviatilis* needs to survive. Invasive plants adversely affect microhabitat in the forest by modifying availability of light and nutrient cycling processes, and by altering soil-water regimes (Smith, 1985). Some invasive plants may release chemicals that inhibit growth of other plants. These competitive advantages allow invasive plants to convert native-dominated plant communities to nonnative plant communities. Over 60 percent of populations (10 of the 16) are now in habitats dominated by alien species (HBMP 2010). Some

of the major invasive species occurring within population units include *Clidemia hirta* (Koster's curse), *Psidium cattleianum* (strawberry guava), *Blechnum occidentale* (hammock Fern), *Pluchea symphitifolia* (bushy fleabane), *Schinus terebinthifolius*(Christmas berry), *Thelypteris parasitica* (parasitic maiden fern), *Psidium guajava* (guava), *Adiantum raddianum* (Delta maidenhair fern), *Paspalum conjugatum* (Hilo grass), *Setaria palmifolia* (palmgrass), *Ageratina riparia* (creeping cottonweed), *Deparia petersenii* (Japanese lady fern), *Oplismenus hirtellus* (basket grass), *Tibouchina herbacae* (glory bush), in the lowland wet areas and *Spathoglottis plicata* (Philippine ground orchid), *Melastoma septemnervium* (asian melastome), *Schinus terebinthifolius*, *Psidium cattleianum*, *Heliocarpus popayanensis* (white moho), *Melinis minutiflora* (molasses grass) and *Paspalum conjugatum* in lowland mesic areas. The degree of threat is proportional to active control of invasive weeds within population unit areas. Since Hawai'i has a year round growing season, if nonnative plant control is not occurring, nonnative plants will likely outcompete *K. fluviatilis* for resources and degrade habitat quality.

Climate change may pose a threat to this species. Fortini et al. (2013) conducted a landscape-based assessment of climate change vulnerability for native plants of Hawai'i using high resolution climate change projections. Climate change vulnerability is defined as the relative inability of a species to display the possible responses necessary for persistence under climate change. This assessment concluded that *Kadua fluviatilis* is highly vulnerable to the impacts of climate change, with a vulnerability score of 0.506 (on a scale of 0 being not vulnerable to 1 being extremely vulnerable to climate change). Therefore, additional management actions may be needed to conserve this taxon into the future, such as locating key microsites that overlap with current and future climate envelopes for outplanting efforts.

Kadua fluviatilis has limited species' adatability to environmental changes since there are low population sizes left in the wild. This species experiences reduced reproductive vigor due to low levels of genetic variability, thereby lessening the probability of long-term persistence (USFWS 2016, p. 67,799).

Inadequate regulatory mechanims threaten *Kadua fluviatilis*. Nonnative feral ungulates pose threat to *Kadua fluviatilis* through destruction and degradation of the species' habitat and herbivory but regulatory mechanisms are inadequate to address this threat (USFWS 2016). The State of Hawai'i provides game mammal (feral pigs and mouflon sheep) hunting opportunities on 38 State-designated public hunting areas on the island of Hawai'i and six public hunting units on the island of Maui (HDLNR 2015, pp. 19-21 and 66-77). However, the State's management objectives for game animals range from maximizing public hunting opportunities (e.g., "sustained yield") in some areas to removal by State staff, or their designees, in other areas (HDLNR 2015, entire).

Introduction of Nonnative Plants and Insects: Currently, four agencies are responsible for inspection of goods arriving in Hawai'i (USFWS 2016, p. 67,843). The Hawai'i Department of Agriculture (HDOA) inspects domestic cargo and vessels and focuses on pests of concern to Hawai'i, especially insects or plant diseases. The U.S. Department of Homeland Security-Customs and Border Protection (CBP) is responsible for inspecting commercial, private, and military vessels and aircraft and related cargo and passengers arriving from foreign locations (USFWS 2016, p. 67,844). The U.S. Department of Agriculture-Animal and Plant Health Inspection Service-Plant Protection and Quarantine (USDA-APHIS-PPQ) inspects propagative plant material, provides identification services for arriving plants and pests, and conducts pest

risk assessments among other activities (HDOA 2009, p. 1). The Service inspects arriving wildlife products, enforces the injurious wildlife provisions of the Lacey Act (18 U.S.C. 42; 16 U.S.C. 3371 *et seq*.), and prosecutes CITES (Convention on International Trade in Wild Fauna and Flora) violations. The State of Hawai‘i allows the importation of most plant taxa, with limited exceptions (USFWS 2016, p. 67,845). It is likely that the introduction of most nonnative invertebrate pests to the State has been and continues to be accidental and incidental to other intentional and permitted activities. Many invasive weeds established on Hawai‘i have currently limited but expanding ranges. Resources available to reduce the spread of these species and counter their negative ecological effects are limited. Control of established pests is largely focused on a few invasive species that cause significant economic or environmental damage to public and private lands, and comprehensive control of an array of invasive pests remains limited in scope (USFWS 2016, p.).

Conservation Actions

The National Tropical Botanical Garden (NTBG) has successfully propagated *Kadua fluviatilis* by seeds and cuttings since 2001 (NTBG 2002). It has been possible to cultivate hundreds of individuals of this species at the NTBG nursery. Several individuals (13) were planted in their living collections at both the McBryde and Limahuli Gardens during 2019-2020. There are 3,221 seeds in storage from 16 different accessions including seeds from population units at Kaipapa‘u on O‘ahu, and seeds from Hanakāp‘i‘ai, Hā‘upu and Upper Mānoa, on Kaua‘i, at the NTBG Seed Bank and Laboratory (NTBG 2019).

Kadua fluviatilis is one of the target endangered plant species that the NTBG is working to conserve within the fenced Lower Limahuli Preserve through the Services’ Partners for Fish and Wildlife Program. The NTBG aims to establish genetically diverse conservation collections within established restoration areas. This project involves collecting propagules, propagating, and translocating individuals, habitat protection, and monitoring *K. fluviatilis* among other T&E plants (NTBG 2019b, p. 4)). Fifteen indivudals were translocated in 2019 within the Lower Limahuli Preserve (NTBG 2019).

The NTBG in partnership with a private landowner and the Services’ Partners for Fish and Wildlife Program, have started to improve the lowland mesic forest habitat were *Kadua fluviatilis* occurs. The project involves removal of nonnative plant species with a focus on *Melastoma septemnervium*, as it currently covers large areas on Mt. Hā‘upu, as well as monitoring ungulate activity to determine how to prevent ungulates from accessing the site (NTBG 2019a). The majority of seeds in storage (2,688 out of 3,221) at NTBG are from accessions from the Mt. Hā‘upu population unit (NTBG 2019).

On O‘ahu conservation actions include surveying and seed collections by the NTBG from the Kaipapa‘u population unit in 1998, these seeds remain in storage at the NTBG Seedbank and Laboratory (NTBG 2013). The Hawai‘i Plant Extinction Prevention Program (*http://pepphi.org*) and Department of Land and Natural Resources, Division of Forestry and Wildlife conducted surveys for *Kadua fluviatilis* at Helemano in 2012, however, no individuals were found (Ching Harbin 2020, pers. comm.).

Regulatory actions such as the Endangered Species Act provide conservation benefits for *Kadua fluviatilis*. The Service determined endangered status under the Endangered Species Act of 1973 (Act), as amended, for 39 plants and 10 animals on October 31, 2016 including *Kadua fluviatilis* (USFWS 2016). The primary purpose of the Act is the conservation of endangered and

threatened species and the ecosystems upon which they depend. The ultimate goal of such conservation efforts is the recovery of these listed species, so that they no longer need the protective measures of the Act. Conservation measures provided to species listed as endangered or threatened under the Act include recognition of threatened or endangered status, recovery planning, requirements for Federal protection, and prohibitions against certain activities. The Act encourages cooperation with the States and requires that recovery actions be carried out for all listed species. The Act and its implementing regulations in addition set forth a series of general prohibitions and exceptions that apply to all endangered wildlife and plants. For plants listed as endangered, the Act prohibits the malicious damage or destruction on areas under Federal jurisdiction and the removal, cutting, digging up, or damaging or destroying of such plants in knowing violation of any State law or regulation, including State criminal trespass law. Certain exceptions to the prohibitions apply to agents of the Service and State conservation agencies. The Service may issue permits to carry out otherwise prohibited activities involving endangered or threatened wildlife and plant species under certain circumstances. With regard to endangered plants, a permit must be issued for scientific purposes or for the enhancement of propagation or survival. For federally listed species unauthorized collecting, handling, possessing, selling, delivering, carrying, or transporting, including import or export across State lines and international boundaries, except for properly documented antique specimens of these taxa at least 100 years old, as defined by section 10(h)(1) of the Act, is prohibited. Damaging or destroying any of the listed plants in addition is violation of the Hawai‘i State law prohibiting the take of listed species. The State of Hawai’i’s endangered species law (HRS, Section 195-D) is automatically invoked when a species is Federally listed, and provides supplemental protection, including prohibiting take of listed species and encouraging conservation by State government agencies. Currently, *Kadua fluviatilis* is only known to be extant on Hawai‘i Department of Land and Natural Resources owned lands and private lands.

CURRENT CONDITION

Historical Condition

Habitat Distribution & Description Trends

Lowland mesic forest occured in the mesic zone betweeen dry leeward and wet windard climates. Vegetation composition was variable ranging from open to dense canopy often with a wide range and high diversity of plant species (Lowe et al. 2019, pp. 6-7). Prior to human arrival, it is estimated that lowland mesic forest covered approximately 126,665 acres (51,259 hectares) on Kaua‘i or 36 percent of total island area (Reeves and Amidon 2018). Substantial areas of lowland mesic forests have been lost or degraded on Kaua‘i due to human activity and the intrusion of invasive trees, shrubs and nonnative grassland communities (Lowe et al. 2019, p. 12). It is estimated that there are currently 13,112 acres (5,306 hectares) or 3.6 percent of the total island area of remaining lowland mesic forest on Kaua‘i (The Nature Conservancy 2006). On O‘ahu, Kadua fluviatilis is not known to occur in lowland mesic forests.

Lowland wet forest is thought to have been the predominant original vegetation of the windward lowlands on the larger main islands (Cuddihy and Stone 1990, p. 8). In pre-human times, a lowland rainforest dominated by *Acacia koa* (koa) was probably widespread below 1,000 meters on the larger islands in windward areas with deep soils. Prior to the arrival of humans, it is estimated that lowland wet forests covered approximately 97,779 acres (39,570 hectares) or 27 percent of Kaua‘i and 63,552 acres (25,719 hectares) or 17 percent of O‘ahu (Reeves and Amidon 2018). It is estimated that current cover of lowland forest has been reduced on Kaua‘i to

only 39,134 acres (15,837 hectares) or 11 percent and to 45,230 acres (18,304 hectares) or 13 percent on Oʻahu (The Nature Conservancy 2006).

Data are not available to estimate the extent of lowland wet shrubland, lowland wet cliff, and lowland mesic shrublands habitats in pre-human times, but it is assumed the quality of these habitats have also declined due to invasive species (Ball et al. 2019, Clark et al. 2019, Lowe et al. 2019, Nelson et al. 2019).

Historic Trends of *Kadua fluviatilis*

Kadua fluviatilis was orginally described by C.N. Forbes in 1910 (Forbes 1913, p. 6). Forbes found the type locality specimen on the borders of the upper Wahiawa stream within the Koʻolau mountain range on Oʻahu. The historical range of *K. fluviatilis* is likely larger than its known current range. This historical range for this species included observations of population units at Kaukonahua in 1915, Kipapa in 1932, and Kaluanui Gulch in 1937 on Oʻahu. More recent observations (1980s to 2012) include population units at Helemano, Opaeula, Kawaiʻiki Gulch, Punaluʻu, Maʻakua, Kaipapaʻu Gulch, and Koloa Gulch on Oʻahu (USFWS 2020, unpubl. data; OANRP 2020, unpubl. data; HBMP 2010). There were 20 to 50 plants at Punaluʻu in 1985, 50 individuals at Opaeula in 1999 and 250 individuals observed at Kawaiʻiki Gulch in 1999 (HBMP 2010). There were at least 200 or 300 mature plants (and additional immature plants) at Kaipapaʻu Gulch in 1998 (HBMP 2010).

On Kauaʻi, population units were observed at Mt. Hāʻupu in 1947 and Waiʻoli, Hanakāpʻiʻai, Hoʻolulu in the 1990s. There were 25 shrubs at Waiʻoli in 1992 and ca. 50-100 plants at Hanakāpʻiʻai in 1996 (HBMP 2010). Wood (2005) observed 400 to 500 individuals of *K. fluviatilis* at Mt. Hāʻupu in 2005, but only 50 to 100 were reported by Tangalin in 2017 (NTBG 2020). Twenty plants were observed by Wood (2014) at ʻIole. In 2008, a single individual was reported in Upper Limahuli Preserve by Tangalin (NTBG 2020) and in 2012, a single individual was found in the Lower Limahuli Preserve, however, the individual could not be re-located the following year (Edmonds 2020, pers. comm.). A single individual was observed at Hoʻolulu in 2020 (Heintzman 2020, pers. comm).

Current Condition

Historically, there were 16 populations of *Kadua fluviatilis* documented from five different habitat types. Some of these populations remain but many have been lost (USFWS 2016, p. 67,799). Given the diversity of habitats that *K. fluviatilis* occupies, it was likely more wide spread. In recent times, this species has been documented on Oʻahu at the Kaipapaʻu population unit (H), and at Punaluʻu and Kaluanui Gulch (G), on Figure 3 below.

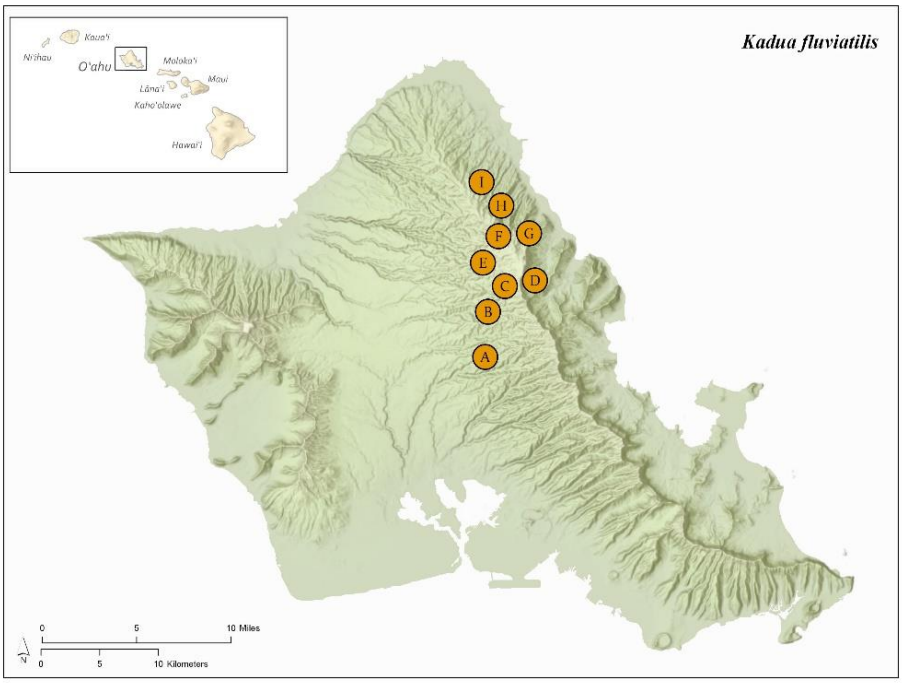

Figure 3. Distribution map of population units of *Kadua fluviatilis* on Oʻahu.

On Kauaʻi, populations units have been recently observed at Hanakāpʻiʻai (N), Mt. Hāʻupu (J), Upper Mānoa (P), Limahuli (P), Hoʻolulu (O) and at ʻIole (L) on the map below (Figure 4). Fifteen individuals were reintroduced into the Lower Limahuli Preserve (P) during 2019 (NTBG 2020). Table 3 summarizes our current understanding of the extant populations of *Kadua fluviatilis* on Oʻahu and Kauaʻi. Currently there are seven known populations, three on Oʻahu and five on Kauaʻi. Ching Harbin estimated the current number of individuals to be under 150 total on Oʻahu (2020, pers. comm.). On Kauaʻi there are an estimated 78 to 128 individuals. Survey efforts for this species have been limited, many locations have not been visited in recent years. Additional survey effort is needed on both islands to more accurately reflect the current status and distribution. Overall, from what is known currently, the number of populations and individuals per population are declining. The number of known populations has declined from 16 populations to seven populations, a 50% decline in the number of populations. There are still extant populations occupying the five different habitat types: lowland wet forest, lowland wet shrubland, lowland mesic forest, lowland mesic shrubland and wet cliff. The current condition of these habitats can be found in the Habitat Status Assessment report for each habitat (Lowe et al. 2019, pp. 8-9; Ball et al. 2019, pp. 8-11, Clark et al. 2019, pp. 7-11). In summary, the quality of the above mentioned ecosystems in the current condition has declined. Likewise, the extent of suitable habitat across the landscape has diminished from the historic condition, both as a result of nonnative species (feral ungulates and plants) among other stressors.

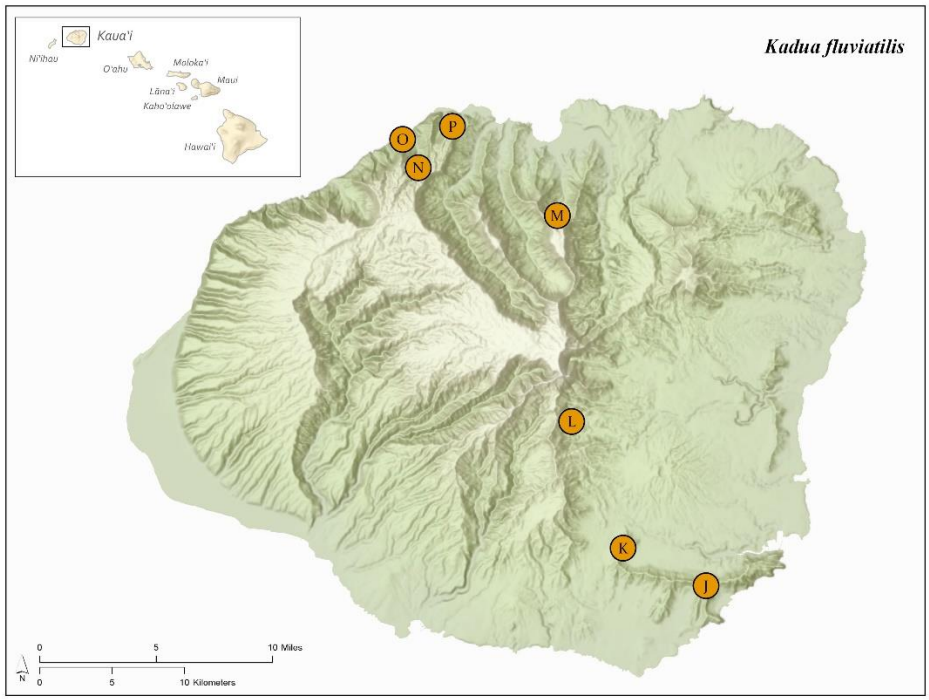

Figure 4. Distribution map of population units of *Kadua fluviatilis* on Kauaʻi.

Table 3. Current Populations Units of *Kadua fluviatilis* by habitat type and island.

Population Unit Name	Punaluʻu & Kaluanui Gulch	Maʻakua & Kaipapaʻu Gulch	Mt. Hāʻupu	ʻIole	Hanakāpʻiʻai	Hoʻolulu	Upper Mānoa & Limahuli
Island	Oʻahu	Oʻahu	Kauai	Kauai	Kauai	Kauai	Kauai
Population Unit Letter	G	H	J & K	L	N	O	P
Habitat Type	Lowland wet forest	Lowland wet shrubland	Lowland mesic forest	Lowland wet forest	Lowland wet shrubland	Lowland mesic shrubland	Lowland wet forest & wet cliff
Last Observation Date*	2018 (Punaluʻu) & 2019 (Kaluanui)	1996 (Maʻakua)& 2013 (Kaipapaʻu)	2005	2012	2018	2020	2017 (Upper Mānoa), 2008 & 2012 (Limahuli)
Extant? (Y/N/Unk)	Y	Y	Y	Y	Y	Y	Y
Population Type	Wild	Wild	Wild	Wild	Wild	Wild	Wild (Upper Mānoa and Limahuli) Reintroduction (Limahuli)
Last observed Number of Individuals	1 (Punaluʻu) & 5 to 10 (Kaluanui)	20 (Kaipapaʻu)	50 to 100 (pop unit J)	20	6	1	1 wild in Upper Mānoa, 1 wild in Limahuli Preserve and 15 reintroduced to Limahuli Preserve

SPECIES VIABILITY SUMMARY

Resiliency

For *Kadua fluviatilis* to maintain viability, the population must be resilient. The definition of resiliency is the ability of the population to withstand stochastic events, meaning they must have healthy, stable populations, good quality and quantity of habitat.

We determine resiliency for *Kadua fluviatilis* based on the metrics of the number of individuals per population, population structure, and the quality of the habitat factors that support the species. In total, 16 populations were known for the species. Populations are considered resilient if they contain large numbers of individuals and a population structure that includes all life stages (seedlings, immature individuals and mature individuals) to support positive or stable population growth. We have limited information on population structure, though mature and immature individuals have been reported within historic population units. Currently, there are two populations on Oʻahu with an estimated maximum of 150 individuals (Ching Harbin, pers. comm. 2020). There are at least five extant populations on Kauaʻi with an estimated 78 to 128 individuals. More surveys are needed to better understand the status of some of the populations that have not been recently observed, especially on Oʻahu (Ching Harbin 2020, pers. comm.). However, we can assume population sizes have decreased, even to the extent that some populations have been lost, and habitat extent and quality have also declined. By additionally considering the persistance of threats in the majority of the population units, there is reduced resiliency in the current condition.

When evaluating the habitat quality of each population to determine the species' resiliency, the following threats; habitat modification and destruction by feral pigs and goats, stocahstic events such as landslides, and competition from nonnative plants combined with herbivory by nonnative ungulates, continue to degrade the suitable habitat for *Kadua fluviatilis* (Table 4).

Table 4. Current threats for each extant population by location of *Kadua fluviatilis* (K = Kauaʻi, O= Oʻahu).

Population Unit Name	Population Unit Letter (Island)	Invasive nonnative plants	Landslides	Feral ungulates
Punaluʻu	G (O)	X	X	X
Kaluanui Gulch	G (O)	X	X	X
Kaipapaʻu	H (O)	X	X	X
Limahuli	P (K)		X	
Mt. Hāʻupu	J (K)		X	X
Hanakāpʻiʻai	N (K)	X	X	X
Hoʻolulu	O (K)	X	X	X
Upper Mānoa	P (K)	X	X	X
ʻIole	L (K)	X	X	X

Overall, the resiliency of *Kadua fluviatilis* is low due to a low number of individuals (227 to 298), and, only two populations are in areas in which some threats are being addressed (invasive plants at Mt. Hāʻupu and invasive plants and feral ungulates at Limahuli). Therefore, the resiliency for *Kadua fluviatilis* on the species level is low in the current condition due to the low of number of individuals, as well as the decrease in the extent and quality of habitat, and the degree of threats remaining in current populations.

Redundancy

We evaluate redundancy for *Kadua fluviatilis* based on the metric of the number of resilient populations and their distribution across the known range of the species. Historically, the species was known from Pūpūkea to Mānoa in the lowland wet forest and lowland wet shrubland habitats of Oʻahu. It is known from several locations on Kauaʻi, from the northern valleys of Waiʻoli, Mānoa, Limahuli, Hanakāpʻiʻai and Hoʻolulu, to the southeastern moutain range of Mt. Hāʻupu and the central ʻIole ridge below the summit of the island at Kawaikini. Since no concentrated efforts focusing on surveying *K. fluviatilis* have been conducted we cannot be certain of the current distribution, however, it is likely populations have been lost due to habitat loss and degradation which decreases redundancy. Currently only two populations are known on Oʻahu and five populations on Kauaʻi. The loss of populations reduces the species range and increases the risk of extirpation. Therefore, redundancy in *K. fluviatilis* is low due to the low resiliency of populations, and the loss of populations and species range constriction.

Representation

We define representation for *Kadua fluviatilis* based on the number of populations occupying the different habitat types used by *K. fluviatilis*.The distribution of historic and current populations occurs in five habitat types on two islands. Lowland wet shubland and lowland wet forest are the only two habitat types for *K. fluviatilis* on Oʻahu. Only two populations are known to be extant on Oʻahu, population units G and H. Population unit G occurrs in lowland wet forest and population H occurs in lowland wet shrubland. Lowland wet forest and lowland wet shrubland also occur on Kauaʻi along with lowland mesic forest, lowland mesic shrubland and lowland wet cliff. There are five known extant population units on Kauaʻi; J, L, N, O and P. Population units L occur in lowland wet forest, J occurs in lowland mesic forest, N occurs in lowland wet shrubland, O occurs in lowland mesic shrubland and P occurs in lowland wet cliff and lowland wet forest. In summary, three population units occur in lowland wet forest and two population units occur in lowland wet shrubland (though on different islands) whereas a single population represents the remaining habitat types. Furthermore, the total number of individuals in each popuation unit represented by more than one habitat type is low (11 to 32 individuals in lowland wet forest and 26 individuals in lowland wet shrubland) thus these populations have low resiliency. Therefore, the habitat types, which are analagous to the breadth of genetic diversity within the species, are not adequately represented. The unique traits which exist in the remaining populations are at risk of being lost. Ideally, several resilient populations would occur within each habitat type. Thus, representation for *K. fluviatilis* is low. *Ex situ* collections provide the potential for increased representation for the populations that are in seed bank facilities.

Summary

The current condition of *Kadua fluviatilis* is described as having seven populations on two islands. Overall, it is likely that individuals in populations have generally been decreasing due to existing threats in suitable habitats. Some redundancy and representation is maintained in *ex situ* seed storage and greenhouses, and reintroduced individuals, however recruitment as a result of these reintroductions had not been documented to be naturally occurring in the wild yet. Since this species has low resiliency, low redundancy, and low representation in the current condition, the overall viability of this species is low (Table 5).

Table 5. Current viability of *Kadua fluviatilis*.

The 3Rs	**Resiliency**	**Redundancy**	**Representation**	**Overall Viability**
Current Condition	Low	Low	Low	Low

LITERATURE CITED

Ball, D., S. Lowe, M.K. Reeves, F. Amidon, and S.E. Miller. 2019. Hawai‘i mesic grassland and shrubland. Editors: M.I. Goldstein and D.A. DellaSala. Encyclopedia of the World’s Biomes, Elsevier, 2020.

Carlquist. S. 1966. The Biota of Long-Distance Dispersal. III. Loss of Dispersibility in the Hawaiian Flora. *Brittonia*, Vol. 18, No. 4 (Oct. - Dec., 1966), pp. 310-335.

Clark, M., M. K. Reeves, F. Amidon, and S. E. Miller. 2019. Hawaiian Islands Wet Forest . Editors: D. A. Dellasala, M. I. Goldstein. Encyclopedia of the World’s Biomes. Elsevier. 2020

Cuddihy, L. W. and C. P. Stone. 1990. Alteration of native Hawaiian vegetation-Effects of humans, their activities and introductions. University of Hawaii, Cooperative National Park Resources Studies Unit. pp.103.

Elliott, D.D. and S.Y. Tamashiro. 2009. Native Plants Hawa‘i Website. http://nativeplants.hawaii.edu/plant/view/Kadua_fluviatilis

Forbes. C. N. 1915. Occasional Papers of the Bernice Pauahi Bishop Museum of Polynesian Ethnology and Natural History, New Hawaiian Plants. – III. Plant Invasion on Lava Flows. Vol V.–No. 1. Bishop Museum Press, Honolulu, HI, 1912. pp. 520.

[HBMP] Hawai‘i Biodiversity Mapping Database, University of Hawai‘i 2010.

[HPPRCC] Hawai‘i and Pacific Plants Recovery Coordinating Committee. 2011. Revised recovery objective guidelines. 8 pp.

Gagné, W.C., and Cuddihy L.W. (1999). Vegetation. In Wagner W.L., Herbst D.R. and Sohmer S.H. (eds.) Revised ed. *Manual of Flowering Plants of Hawai‘i*. pp 45-115. Honolulu: University of Hawai‘i Press, Bishop Museum Press.

Groeninckx I., S. Dessein , H. Ochoterena, C. Persson, T. J. Motley, J. Karehed, B. Bremer, S. Huysmans, and E. Smets. Phylogeny of the Herbaceous Tribe Spermacoceae (Rubiaceae) Based on Plastid DNA Data. Annals of the Missouri Botanical Garden 96: 109–132. 23 April 2009.

[IUCN] International Union for Conservation of Nature. 2013. IUCN Guidelines for Reintroductions and Other Conservation Translocations. Version 1.0. Gland, Switzerland: IUCN Species Survival Commission, viiii + 57 pp.

Karehed, J. & B. Bremer. 2007. The systematics of Knoxieae (Rubiaceae)—Molecular data and their taxonomic consequences. Taxon 56: 1051–1076.

Lorence D. H., W.L. Wagner, W.G. Laidlaw. 2010. Kadua haupuensis (Rubiaceae: Spermacoceae), a new endemic species from Kaua‘i, Hawaiian Islands. Brittonia 62(2), 2010, pp. 137-144.

Lilleeng-Rosenberger, K. 1996. The Native Hawaiian Plant Propagation Database. College of Tropical Agriculture and Human Resources, University of Hawai‘i. https://www.ctahr.hawaii.edu/hawnprop/plants/hed-fluv.htm

Lowe S., D.L Ball, M.K Reeves, F. Amidon, and S. E Miller. 2019 Hawai‘i Mesic Forest. Editors: M.I. Goldstein and D.A. DellaSala, Encyclopedia of the World’s Biomes, Elsevier, 2020.

[NTBG] National Tropical Botanical Garden Controlled Propagation Facility. 2002. Report on controlled propagation of listed and candidate species, as designated under the U.S. Endangered Species Act. Unpublished report submitted to the U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, Hawaii.

[NTBG] National Tropical Botanical Garden Controlled Propagation Facility. 2019. Report on controlled propagation of listed and candidate species, as designated under the U.S. Endangered Species Act. Unpublished report submitted to the U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, Hawaii.

[NTBG] 2013. NTBG database herbarium specimen detail for *Kadua fluviatilis*. Voucher number, KRW 7557. OCT 1998**.**

[NTBG] National Tropical Botanical Garden. 2019a. Mt. Hā‘upu Conservation Project, Partners for Fish and Wildlife Project Annual Report to the U.S. Fish and Wildlife Service. Unpublished.

[NTBG] National Tropical Botanical Garden. 2019b. Limahuli Preserve Rare Plant Conservation Collections and Habitat Restoration ProjectProject, Partners for Fish and Wildlife Project Annual Report to the U.S. Fish and Wildlife Service. Unpublished.

[NTBG] 2020. NTBG database multiple herbarium specimens detail for *Kadua fluviatilis*. Accessed by Michelle Clark, May 1 – 20, 2020.

[OARNP] O‘ahu Army Natural Resource Program, Army Environmental Population Reference Site Summary Report. 15 April 2020.

Sakai, A., Wagner, W., Ferguson, D., and D. Herbst. 1995. Origins of dioecy in the Hawaiian flora. Ecology 76(8):2517-2529.

Smith, C.W. (1985). Impact of alien plants on Hawai‘i’s native biota. In Stone C.P. and Scott J.M. (eds.) *Hawai‘i’s terrestrial ecosystems preservation and management*. pp. 180-250. Honolulu: Cooperative National Park Resources Study Unit, University of Hawai‘i.

The Nature Conservancy of Hawai‘i. 2006. Hawai‘i Islands Ecoregions. The Nature Conservancy of Hawai‘i. pp. 9.

Terrell E. E., H.E. Robinson, W.L. Wagner, and D. H. Lorence. 2005. Resurrection of Genus Kadua for Hawaiian Hedyotidinae (Rubiaceae), with Emphasis on Seed and Fruit Characters and Notes on South Pacific Species. Systematic Botany (2005), 30(4): pp. 818-833.

[USFWS] U.S. Fish and Wildlife Service. 2016. Endangered and Threatened Wildlife and Plants; Endangered Status for 49 Species from the Hawaiian Islands. Federal Register 81, (190): 67789-67860.

[USFWS] U.S. Fish and Wildlife Service. 2016. USFWS Species Status Assessment Framework. Version 3.4 dated August 2016.

[USFWS] 2020. Unpublished data. U.S. Fish and Wildlife Service, Pacific Islands Field Office, Honolulu, Hawai‘i.

[USFWS] 2020. Unpublished data. U.S. Fish and Wildlife Service, Pacific Islands Field Office, Honolulu, Hawai‘i.

Wagner, W. L., D. R. Herbst, and S. H. Sohmer. 1999. Manual of the Flowering Plants of Hawaii. 1919 pp. in 2 volumes.

Wikstrom, S. N., J. Karehed, T. J. Motley and B. Bremer. 2013. Phylogeny of *Hedyotis* L. (Rubiaceae: Spermacoceae): Redefining a complex Asian-Pacific assemblage. Taxon 62(2), April 2013: 357–374

Wood K.R. 2005. Summary Report of Botanical Research at Hā‘upu Summit, Kaua‘i, Hawai‘i. National Tropical Botancial Garden. pp. 24

Wood K.R. 2014. Botanical Survey Report for the Windward Slopes South of Kawaikini including ‘Ili‘ili‘ula, ‘Iole and Wai‘ahi Headwaters, Kaua‘i, Hawai‘i. National Tropical Botancial Garden. pp. 48.

Personal Communication

Ching Harbin, S. 2020. *Kadua fluviatilis* Species Report. Email to Michelle Clark, Pacific Islands Fish and Wildlife Office, 15 April 2020.

Weisenberger, L. Conservation Actions on O‘ahu for *K. fluviatilis*. Email to Michelle Clark, Pacific Islands Fish and Wildlife Office, 14 May 2020.

Heintzman, S. 2020. Kadua fluviatilis at Ho‘olulu. Email to Michelle Clark, Pacific Islands Fish and Wildlife Office, 6 June 2020.